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Effect of Reed Quality on the Breeding Success of the Great Reed Warbler *Acrocephalus arundinaceus* (Passeriformes, Sylviidae)

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Abstract: The effects of physical variables of the reed (*e.g.* the diameter and density of the reed stems) on the breeding success of the Great Reed Warbler were studied in the cases of the nest-supporting reed stems and the stems in the surroundings of 124 nests in three different reed habitats (mining ponds, small canals and large canals). The mean diameter of the nest-supporting stems correlated positively with the mean diameter of the stems in the surroundings. The diameters of both the nest-supporting reed stems and the stems in the surroundings varied significantly between the three reed habitats, whereas the density of the stems in the surroundings did not. We subdivided the reed densities into three categories: "sparse" (50-160 stems/m^2), "intermediate" (160-270 stems/m^2) and "dense" (270-380 stems/m^2). The Great Reed Warbler significantly preferred the intermediate reed density for breeding, while the highest breeding success was recorded in the dense reed. However, the clutch survival did not differ between the three reed density categories. Whereas the intermediate reed density was mostly used by the Great Reed Warbler for nesting, this was not the subgroup with the highest breeding success, probably because of the different predation types.

Keywords: Reed density, reed stem diameter, nest-supporting stem, Mayfield's method, reed management, Serbia

Introduction

The Great Reed Warbler *Acrocephalus arundinaceus* Linnaeus, 1758 inhabits reed *Phragmites australis* habitats in middle latitudes of the western Palaearctic (Cramp 1998). This species uses strong, tall and dense reed for nesting in habitats such as reed beds in marshes, fishponds, mining ponds, canals or the banks of shallow, sluggish, lowland rivers (Leisler 1981, Nilsson, Persson 1986, van Der Hut 1986, Cramp 1998, Graveland 1998, Prokešová, Kocian 2004, Batáry, Báldi 2005, Mérő *et al*. 2014). The area sensitivity, the fragmentation sensitivity and the habitat quality of the reed beds are key factors that can affect the occurrence of strictly reed bed-related bird species such as the Great Reed Warbler (Foppen, Graveland 1999, Benassi *et al*. 2009, Bosschieter *et al*. 2010, Benassi, Battisti 2011, Mortelliti *et al*. 2012). However, the Great Reed Warbler selects its territory near or at the edge of the reed bed (Báldi 1999, Báldi, Kisbenedek 1999, 2000), and the clutches are raised within the first few metres of the reed edge, mainly adjacent to open water (Honza *et al*. 1993, Bensch 1993, Graveland 1998, Petro *et al*. 1998). Graveland (1998) reported basic findings relating to the physical variables (*e.g.* the nest-supporting reed stem diameter and the reed stem density) in reed beds housing Great Reed Warbler nests, while Dyrcz (1981) presented information on the proportions of old and new nest-supporting reed stems. As in other reed passerine species, the reed stem density is a relevant parameter in the breeding of the Great Reed Warbler. The density can be affected considerably by the reed management, *i.e.* reed burning or reed cutting in winter (Vadász *et al.* 2008, Báldi, Moskát 1995).

Here we report on the physical characteristics, *i.e.* the variables of the reed as concerns the reed stem diameter, the number of nest-supporting reed stems (abbreviated below "supporting stems") and the density of reed stems in the surroundings of the Great Reed Warbler nests. The aims of this study were (1) to determine the physical variables of the supporting stems and the stems in the surroundings; (2) to examine the relationships between the mean diameter of the supporting stems and that of the stems in the surroundings, and between the density of the stems in the surroundings and the number of supporting stems; (3) to establish the differences in mean density of the stems in the surroundings, in the mean number of supporting stems per nest and in the diameters of both the stems in the surroundings and the supporting stems between three reed habitats: mining ponds, small canals and large canals; and (4) to investigate the differences in the breeding success of the Great Reed Warbler in three reed density categories: "sparse", "intermediate" and "dense" (defined in detail in the Material and Methods).

Material and Methods

The study was performed in the region of Sombor municipality (1178 km^2), which lies in the northwestern part of the northern Serbian province of Vojvodina. Sampling was carried out at 11 locations in three different reed habitats (mining ponds, large canals and small canals) (Table 1). The mining ponds resulted from the excavation of clay or sand for the local brickyards. The water level in the mining ponds depends both on the precipitation in autumn, winter and early spring and on the level of the groundwater. In summer and autumn, the water level decreases to an extent related to the intensity of the evapotranspiration of the reed. The nests of the Great Reed Warbler were located in the reed edge, within 5 m of the open water. The developed canal network in Vojvodina constitutes part of the Danube-Tisza-Danube River hydro-system. The small canals are mainly melioration or irrigation canals used in the agricultural water management (Table 1). Both the large and small canals contain a narrow (1 to 5 m) reed belt on their banks where the Great Reed Warbler raises its brood less than a metre from the water. The water level in both canal habitats is regulated by the local "Zapadna Bačka" Water Management Company. While the water supply of the large canals mainly originates from the Danube River, the water level in the small canals depends mostly on the amount of precipitation.

Nests were surveyed at 11 locations throughout the entire breeding season in May, June and July 2011. The physical variables of the reed stems at 124 Great Reed Warbler nests and their surroundings were determined. The diameters of both the supporting stems and the stems in the surroundings were measured; the number of supporting stems was recorded, and the number of stems in the surroundings was counted in a circle 50 cm in diameter and was extrapolated to an area of 1 m^2. The reed densities in the surroundings ranged from 50 to 380 stems/m^2, and were subdivided into three arithmetically equal categories: "sparse" (50-160 stems/m^2), "intermediate" (160-270 stems/m^2) and "dense" (270-380 stems/m^2). Such an approach appeared reasonable as we wished to ensure the random selection of the nests in the three reed density categories. All nests found were regularly checked every fifth or sixth day, when the number of eggs, the number of nestlings and the loss of eggs, the loss of nestlings or the loss of the whole nest were recorded.

The basic descriptive statistics (means with standard deviation (SD) given in brackets) of the reed variables were calculated for the supporting stems, for the old and new stems in the surroundings and for both together. We used the non-parametric Spearman correlation to check the relationship between the mean diameters of the supporting stems and the stems in the surroundings, separately for the old and new stems too. The Spearman correlation was again utilised to detect the possible existence of a relationship between the density of stems in the surroundings and the number of supporting stems. One-way ANOVA was used to explore the differences in density of the stems in the surroundings, the number of supporting stems per nest, and the diameters of the stems in the surroundings and the supporting stems (mean values) between the three reed habitats (Table 1). The one-way ANOVA was followed by Tukey's HSD *post hoc* test. Egg-days and nestling-days (Mayfield 1975) were considered to calculate the breeding success in the three reed stem density categories. The J-test (calculated in the program of Halupka 2009) was used to compare two Mayfield statistics, *i.e.* the daily survival rates of the eggs and the nestlings (Johnson 1979, Hensler, Nichols 1981). The "breeding success rate" was derived from the Mayfield method by Johnson (1979) and Hensler, Nichols (1981), where the number of egg-days, the number of eggs lost, the number of nestling-days and the number of nestlings lost were the basic data. The "hatching rate" is the ratio of the number of hatched nestlings and the number of eggs immediately before hatching. We used Student's t-test to check the differences in breeding success between the three reed density categories. The rates of survival of the clutches in the various reed density categories were examined with the log-rank test (corresponding to the Mantel-Cox test). Statistical analyses were carried out with the SPSS and the R statistical environment software package (Version 2.13.0; Oksanen *et al*. 2011).

Results

The number of supporting stems varied from 2 to 11 (5.3 ± 1.79), while their diameter varied between 2.5 and 14.0 mm (7.3 ± 1.71 mm). The diameter of the stems in the surroundings ranged from 2.0 to 14.0 mm (7.3 ± 1.55 mm), being from 2.0 to 14.0 mm (6.3 ± 2.38 mm) for the old stems, and from 3.0 to 14.0 mm (7.9 ± 1.57 mm) for the new stems. The mean density of the stems in the surroundings in this study was 219.0 ± 62.15/m^2 (old reed: 100.8 ± 44.72/m^2; new reed: 118.2 ± 37.84/m^2).

The diameter of the supporting stems showed a strong positive correlation with the diameter of the stems in the surroundings (Spearman, rho_{124} = 0.769, $p < 0.0001$; Fig. 1). There were also significant positive correlations between the diameters of the old and the new supporting stems and those of the old and the new stems in the surroundings (old reed, rho_{124} = 0.444, $p < 0.0001$; new reed, rho_{124} = 0.378, $p < 0.0001$). The density of the stems in the surroundings similarly correlated positively with the number of supporting stems (rho_{124} = 0.405, $p < 0.0001$; Table 3).

The density of the stems in the surroundings did not differ (one-way ANOVA, $F_{3,5}$ = 0.927, p = 0.3985), while the number of supporting stems varied significantly between the three habitats, with the mining ponds displaying the densest reed ($F_{3,3}$ = 19.870, $p < 0.0001$; Tukey's HSD test, mining ponds vs. large canals, q = 8.897, $p < 0.0001$; mining ponds vs. small canals, q = 4.871, $p < 0.001$; Table 2). The diameters of the stems in the surroundings ($F_{16,4}$ = 24.940, $p < 0.0001$; mining ponds vs. large canals, q = 8.636, $p < 0.0001$; large canals vs. small canals, q = 7.200, $p < 0.0001$; Table 2) and the supporting stems ($F_{17,2}$ = 23.780, $p < 0.0001$; mining ponds vs. large canals, q = 9.109, $p < 0.0001$; large canals vs. small canals, q = 5.857, $p < 0.0001$; Table 2) revealed significant differences between the three reed habitats.

The Great Reed Warbler significantly preferred the intermediate reed density (7.4 mm mean reed stem diameter) to raise its clutches (t_2 = 5.654, p = 0.0299; Table 3), but the breeding success was highest in the dense reed (t-test, t_2 = 9.062, p = 0.0120; Table 4). The rates of survival of the clutches did not differ considerably in the three reed density categories (log-rank test, χ^2_2 = 1.943, p = 0.3785; Table 4). As regards the Mayfield method, we found differences between the daily survival rates of eggs and nestlings only in the sparse reed (Table 4).

Discussion

In the present study, the diameter of the supporting stems averaged 7.3 mm (sparse reed: 7.9 mm; intermediate reed: 7.3 mm; dense reed: 6.7 mm), which is similar to the data reported by Graveland (1998): he found that the diameter of the supporting stems at De Weerribben Lake was 6.2 mm and at Zwarte Meer was 8.0 mm. Accordingly, there are no major differences in reed stem diameter as concerns the choice of supporting stems by the Great Reed Warbler between the study sites in The Netherlands and Serbia. The reed density recorded at De Weerribben Lake (213 stems/m^2) corresponds to the intermediate reed density in our study, while that at Zwarte Meer (335 stems/m^2) falls in our dense reed category. As in our study, Graveland (1998) considered both old and new stems in estimating the reed density. Dyrcz (1981, 1986) reported that the Great Reed Warbler raises clutches at sites where thick reed stems grow, but he did not provide precise stem diameter data.

Our results suggest that the Great Reed Warbler tends to choose the reed stems for nest-building rather at random (at least in respect of the parameters considered in this study): there was a significant positive correlation between the diameter of the supporting stems and that of the stems in the surroundings (Fig. 1), and also a positive correlation between the number of supporting stems and the reed density, *i.e*. the Great Reed Warbler used more supporting stems in constructing a nest in dense reed than in sparse reed (Table 2). The randomness may even rarely extend to the plant species selected for clutch rising: Mérő, Žuljević (2013) found two non-reed-supported Great Reed Warbler nests, one on Mugwort *Artemisia vulgaris* and one on Marshmallow *Althaea officinalis*, where these plants grew among dense reed.

A reasonable explanation as to why the number of supporting stems was largest on the mining ponds (Table 2) is that there was little reed management at these habitats, whereas canals are often managed annually, rather through mowing than through burning. However, Great Reed Warbler nests were recorded in both non-managed and managed reed habitats. Dyrcz

Table 1. Central coordinates and extents of the study sites and the numbers of nests found

Habitat	**Location**	**UTM CR coordinate**	**Extent of area surveyed**	**Number of nests found**
Mining ponds	Bager	57 22	1.3 ha	20
	Gakovo	58 14	1.4 ha	10
	Pista	47 88	0.7 ha	5
Large canals	Veliki bački kanal	56 18	4.0 km	17
	Plazović - Bački Monoštor	47 33	2.0 km	32
	Plazović - Bezdan	47 18	1.0 km	9
	Plazović - Kolut	48 02	1.0 km	11
Small canals	Eastern Mostonga	57 53	1.0 km	8
	Northern Mostonga	57 14	0.5 km	2
	Stara Mostonga	56 18	0.5 km	1
	Gradina lateral	66 27	1.0 km	9
Total				**124**

Table 2. Physical variables of the reed at the locations of Great Reed Warbler nests in the three habitats

Physical variables of reed		**Mining ponds**	**Large canals**	**Small canals**
Stems in the surroundings	Mean density per m^2	225.4	211.2	202.6
	Mean diameter (mm)	6.4	8.1	6.4
Supporting stems	Mean number	6.7	4.7	5.2
	Mean diameter (mm)	6.1	8.1	6.5

Table 3. Physical variables of the reed at the locations of Great Reed Warbler nests, separately for the three reed density categories

Physical variables of reed		**Sparse reed**	**Intermediate reed**	**Dense reed**
Stems in the surroundings	Mean density per m^2	137.3	206.1	297.9
	Mean diameter (mm)	7.7	7.4	6.9
Supporting stems	Mean number	4.3	5.3	6.3
	Mean diameter (mm)	7.9	7.3	6.7
Proportion of found nests (%)		20.4	50.8	28.8

Table 4. Breeding success of the Great Reed Warbler in the three reed density categories; the clutch size and the number of fledglings are given with standard deviation (SD). *: level of significance between egg and nestling daily survival rates ($p < 0.05$)

Breeding parameters	**Sparse reed**	**Intermediate reed**	**Dense reed**
Breeding success rate (Mayfield 1975)	0.467	0.628	0.686
z value (Johnson 1979, Hensler, Nichols 1981)	2.302	1.524	1.246
p value	0.0213*	0.1276	0.2125
Hatching rate	0.934	0.921	0.942
Mean clutch size	3.4 ± 1.57	4.3 ± 1.47	4.4 ± 1.23
Mean number of fledglings	1.9 ± 2.20	3.1 ± 2.08	3.4 ± 2.01

(1981) and Mérő *et al*. (2014) likewise found Great Reed Warbler nests in both mixed reed (old and fresh stems) and fresh reed, but with a higher proportion of clutches in the mixed reed. Vadász *et al*. (2008) reported that the Great Reed Warbler favoured both, the interior regions of cut and non-cut reed beds. This species demonstrates a strong positive preference for the newly cut areas because of the new formation at the edges (Vadász *et al*. 2008), since it is an "edge species" in reed stands (Báldi, Kisbenedek 1999, Báldi, Kisbenedek 2000, Báldi 2004). Similarly to our results, Vadász *et al*. (2008) found that a rela-

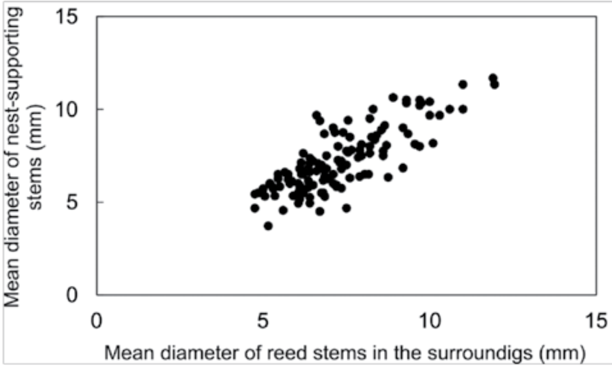

Fig. 1. Spearman correlation between the mean diameters of the supporting stems and the stems in the surroundings

tively low reed density was highly acceptable to the Great Reed Warbler. Our study revealed that the Great Reed Warbler raised more clutches in the intermediate reed density, whereas the breeding success was higher in the dense reed. We presume that dense reed might protect the nests better from predators that attack the clutch from above, *e.g*. the Little Bittern *Ixobrychus minutus* (Mérő *et al*. 2013, Mérő *et al*. 2014), the Marsh Harrier *Circus aeruginosus* (Dyrcz 1981), the Hooded Crow *Corvus cornix,* and the Night Heron *Nycticorax nycticorax* (Mérő *et al*. 2013). The predators which attack the nests from below, *e.g*. the American Mink *Mustella vison* (Bensch 1993) and the Grass Snake *Natrix natrix* (Mérő *et al*. 2014), are probably equally potential dangers for the clutches in all three reed densities, since these predators often rely more on their senses of smell and hearing in finding the prey. However, the loss of clutches can also be affected by rainy and cold weather circumstances (Beier 1981, Fischer 1994, Mérő *et al*. 2013, Mérő *et al*. 2014), when the reed density is likely to have less effect.

In conclusion, we found that the mean reed stem diameter and the reed density hardly differed from those at other study sites in Europe, despite the great geographical distance, *e.g*. between the two lakes in The Netherlands (Graveland 1998) and Serbia (this study). Our results indicate that the Great Reed Warbler tends to select reed stems for nest-building rather at random. However, this may be due to the fine scale of the habitat selected in this study. Therefore, we suggest that further studies should be conducted on a broader scale (*e.g.* patch or landscape scale) in order to confirm or disprove our finding. The diameters of both the stems in the surroundings and the supporting stems exhibited rather large fluctuations between the various reed habitats, which leads to the assumption that the soil quality and other factors may affect the reed variables. Furthermore, we found conclusively that the reed density preference of the Great Reed Warbler did not correlate with the breeding success.

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